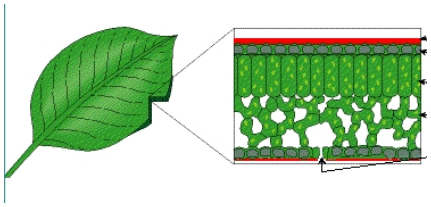
The Plant Game credit: Elena DiMuzio at the Cornell Institute for Plant Biology Teachers

I rewrote some of the explanatory material but the game idea is hers.



Rules:

First of all, to win at any game, players must understand the rules and have a strategy for getting the most points within those boundaries. In most games the winning strategies have the player go on the offensive, taking advantage of current conditions, including what the other players are doing. At the same time, if everyone else gangs up on you, a defensive strategy may be needed, and it is a good idea to plan ahead for this, so you can immediately adopt it when things go wrong.

Living organisms have the equivalent of strategies for survival, although this mostly means they have several built-in responses (genetically programmed) that are triggered by certain environmental conditions (the 'other players' in the game). Organisms have modified their strategies to take into account the strategies of other organisms, they fit into a window of opportunity called a 'niche' (*neesh*). This can mean that one organism takes advantage of what another organism produces as a by-product, but has the disadvantage that many organisms are not well suited to new environments or the presence of a new organism. It takes many generations with many offspring to develop new strategies.

In this lab, you and your partners will try to devise a strategy that will allow your plant to thrive and reproduce (make flowers).

What constitutes winning: make the most flowers before a killing frost occurs. Flowers are the reproductive organ of flowering plants, so winning means producing the most fertile seeds before the plant dies and cannot support the seeds.

Background: The plant has to be established as an mature organism (adult) before it can reproduce . When a seed sprouts it pushes out a first root into the soil and a first shoot towards the sunlight. Both are necessary in order to produce energy: the leaves convert carbon dioxide and water to sugar using the suns energy. The more leaves you make the more sugar you make. In this game, sugar is the 'bank': you spend from the bank to make leaves, roots and flowers. You have to have a certain excess of energy to start making flowers.

It seems like making tons of leaves is the obvious way to win. However, leaves have a large surface area, so they lost some of the water the roots pull up (transpire). To make energy you have balance roots and shoots (most plants have as many roots underground as they have branches above ground). The plant must have a constant supply of water.

In order to get water, it is not just the balance of roots and branches that matters, but how much water each root can pull up, that is the environment (how much groundwater there is versus how much rain).

In order to get the suns energy the amount of sunshine in the needed wavelengths is also important: when the skies are very cloudy many plants grow slowly, even when there is lots of water.

In this game we are going to model variation in water, but you could also do it by modeling variation in light, or the availability of nitrogen.

Game pieces, per team

20 paper clips ('roots')	1 Pasteur pipette and bulb
20 green leaf tokens	1 100ml beaker (water reservoir)
40 gold sugar tokens	1 100-ml graduated cylinder, full
10 red flower tokens	1 straw or bamboo skewer (or straw)
1 die	
1 Weather Table	1 calculator
1 Growth Costs sheet	Score card

Starting the game:

1. Begin with a seedling: thread one paper clip and one leaf over the skewer. Balance the skewer on the graduated cylinder, with the root in the water.
2. Change the weather, roll the die! A TA (Mother Nature) will roll a diel to find out today's weather/water allotment. From the Weather Table, determine what this means about the outcome for your seedline, and decide what strategy you are going to follow. For example, on a sunny day you will be able to make a lot of sugar, if you have enough water, cloudy means not so much sugar, but catching up on water, dry means you might lose a lot of water in transpiration, etc. The Weather table shows you how much photosynthesis (making sugar) you can carry out and how the water balance will work. You have to remove some water from your graduated cylinder every time you make a sugar, and you can replenish it on rainy days.

Example: rolling a '4' = warm and partly sunny, so you can make 3 sugars for every leaf you have, but you will lost 2 ml of water (one 'full' pipette) for each leaf.

3. Acquire some energy based on the roll of the die: Calculate the number of sugars you now have (12 in the example) and how much water you have to remove from the cylinder (6 ml, or 3 full pipettes). Put the tokens next to your score card, put the water in the discard beakers.
4. Costs to build your plant: you may simply roll the die for a few days, but once you have enough sugar, you will invest it in more leaves, roots and eventually, flowers. Trade in sugar tokens for plant parts according to the Growth Cost sheet (leaf = 10 sugar tokens, root = 10 sugar tokens, flower = 20 sugar tokens) . You can only win if you have flowers, but you can choose how much sugar to have in reserve.

    a. Once your roots are out of water you cannot make sugar, and you continue to lose water (transpiration). You can still build body parts if you have stored sugar, even without water.
    b. Once you run out of sugar and you have no water, the plant is dead. Count your flowers – this is your score.
5. After 15 days, Mother Nature will start rolling a pair of Master Weather Dice. As soon as a pair comes up, a hard freeze has occurred and all the plants are dead. If not pair comes up, Mother Nature will roll one of the die again as daily weather outcome.
    a. Count your flowers, this is your score.

Data analysis: write the answers to the following questions, using complete sentences in your descriptions, and showing calculations.

1. Make a graph showing how your plant developed: the x-axis is 'days' and the y-axis is Total Number.
    a. Using a green marker , for each day show how many leaves you had.
    b. Using a brown marker, for each day show how many roots you had.
    c. Using a red marker, for each day show how many flowers you had.
2. Compare the graphs of everyone in the class – how difference was the growth of these plants during this 'season'?
    a. For each leaf, what was the average number on each day (add the number of leaves and divide by the number of plants = players).
    b. For each root, what was the average number on each day
    c. For each flower, what was the average number on each day
3. What characteristics did the winning strategies have? For example more leaves than roots early on, flowers as soon as possible)?
4. Divide the number of leaves by the number of roots in your plant for the final day. This is the 'leaf ratio'. Combine all of the leaf ratios for the class, and make a histogram, showing the leaf ratio on the x axis and the number of flowers on the y-axis.
    a. What does the histogram tell you about winning strategies?
    b. Will the histogram look the same no matter what the weather is?
5. Summarize your strategy, explaining its weak points, strong points and how you did through extended rainy periods or droughts (if you had any). Explain whether it was a good strategy to invest in a flower very early, or build up your sugar reserve. Explain what extreme conditions might require a difference strategy.

Weather Table

Number on Die	Weather	Photosynthesis	Rainfall versus Transpiration
1	Chilly, hard rain	none	Add 20 ml water
2	Cool, light rain	1 sugar x # leaves	Add 5 ml of water
3	Humid and overcast	2 sugars x # leaves	Subtract (1 ml water x # leaves)
4	Warm, partly sunny	3 sugars x # leaves	Subtract (2 ml water x # leaves)

5	Humid and sunny	4 sugars x # leaves	Subtract (2 ml water x # leaves)
6	Sunny, dry	4 sugars x # leaves	Subtract (4 ml water x # leaves)

Scorecard

Day	Die	# leaves X photosynthesis factor = sugar tokens to take	Total sugars available	Number of leaves, roots, flowers (L/R/F)	Return how many sugars? Lx10, Rx10, Fx20	Sugars in reserve (total minus spent)
1				L: R: F:		
2				L: R: F:		
3				L: R: F:		
4				L: R: F:		
5				L: R: F:		
6				L: R: F:		
7				L: R: F:		
8				L: R: F:		
9				L: R: F:		
10				L: R: F:		
11				L: R: F:		
12				L: R:		

				F:		
13				L: R: F:		
14				L: R: F:		
15				L: R: F:		
16				L: R: F:		
17				L: R: F:		
18				L: R: F:		
19				L: R: F:		
20				L: R: F:		
21				L: R: F:		
22				L: R: F:		
23				L: R: F:		
24				L: R: F:		
25				L: R: F:		
26				L: R: F:		
27				L: R: F:		
28				L:		

				R: F:		
29				L: R: F:		
30				L: R: F:		
31				L: R: F:		
32				L: R: F:		
33				L: R: F:		
34				L: R: F:		
35				L: R: F:		
36				L: R: F:		